Designing and Understanding Adaptive Group Behavior

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Overview by
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Summary

– Introduction
– All about BEHAVIORs
– Basis set of Behaviors
– Experimental Environment
– Basis Behavior Algorithms
– Behavior in Heterogeneous Groups
– Composing Higher Level Behaviors
– Compound Behavior Algorithms
– Conclusion/References
Introduction

• Motivation for MAS
• Behavior approach -> Inspired by nature
• This research try to define Basis Behavior Set as general building blocks for more complex behaviors.
• Architecture for combining
Behavior in MAS

• Behaviors can be defined as control laws of the System to effectively achieve and maintain its goals, and basis behaviors are members of a minimal set of such behaviors. (Mataric 1995)

• Biology provides evidence in support of basis behavior.
  – “Motor” control (Human arm grasp, throw..)
Selecting Basis Behaviors

- No METRIC for optimal selecting
- Related to the DOMAIN and GOALS
- Desirable criteria for selecting and evaluating BBS

A basis behavior set should contain only behaviors that are necessary in the sense that each either achieves, or helps achieve, a relevant goal that cannot be achieved with other behaviors in the set and cannot be reduced to them. BBS should be sufficient for accomplishing the goals in a given domain so no other basis behaviors are necessary. Finally, basis behaviors should be simple, local, stable, robust, and scalable. (Mataric 1994a)
BBS for Locomotion

- GB in spatial domain are:
  - GOAL DRIVEN
  - SPATIO TEMPORAL

<table>
<thead>
<tr>
<th>Safe–Wandering</th>
<th>the ability of a group of agents to move about while avoiding collisions with obstacles and each other.</th>
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<tbody>
<tr>
<td>Following</td>
<td>the ability of an agent to move behind another retracing its path and maintaining a line or queue.</td>
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<tr>
<td>Dispersion</td>
<td>the ability of a group of agents to spread out in order to establish and maintain some minimum inter–agent distance.</td>
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<td>Aggregation</td>
<td>the ability of a group of agents to gather in order to establish and maintain some maximum inter–agent distance.</td>
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<tr>
<td>Homing</td>
<td>the ability to find a particular region or location.</td>
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</tbody>
</table>

(Mataric 1995)
Experimental Environment

• Two different Experimental domains
  – SIMULATION ➔ Interaction Modeler
  – Physical Robots
    • “The Nerd Herd”
    • 20 fully autonomous mobile robots
    • Processing and power on board
    • Four wheels, bump sensor around
    • Gripper for carrying objects
    • Radio System for localization

Problems - Physical Environment
Uncertainty, sensor and effectors error

http://robotics.usc.edu/?l=Robots:Retired
BBS Algorithms

• Safe-Wandering

*the ability of a group of agents to move about while avoiding collisions with obstacles and each other.*

Safe-Wander:

Avoid-Kin:
Whenever an agent is within d_avoid
   If the nearest agent is on the left
      turn right
   otherwise turn left.

Avoid-Everything-Else:
Whenever an obstacle is within d_avoid
   If an obstacle is on the right only, turn left.

   If an obstacle is on the left only, turn right.
   After 3 consecutive identical turns, backup and turn.

   If an obstacle is on both sides, stop and wait.
   If an obstacle persists on both sides, turn randomly and back up.

Move-Around:
Otherwise move forward by d_forward, turn randomly.

(Mataric 1995)
BBS Algorithms

• Following

the ability of an agent to move behind another retracing its path and maintaining a line or queue.

Follow:
Whenever an agent is within d_follow
  If an agent is on the right only, turn right.
  If an agent is on the left only, turn left.

(Mataric 1995)

Following is achieved with a simple rule that steers the follower to the position of the leader, and can be implemented as a complement of the Avoid-Everything-Else behavior.
Safe-Wandering + Following more complex global behavior.
BBS Algorithms

• Results of Following BBS

Mataric (1995)
• Dispersion

the ability of a group of agents to spread out in order to establish and maintain some minimum inter-agent distance.

Disperse:
Whenever one or more agents are within d_disperse move away from Centroid_disperse.

(Mataric 1995)

The algorithm computes the local centroid to determine the density distribution of nearby agents, and moves away from the area of highest density.
BBS Algorithms

- Results of Dispersion BBS

(Mataric 1995)
BBS Algorithms

• Aggregation

the ability of a group of agents to gather in order to establish and maintain some maximum inter-agent distance.

Aggregate:
Whenever nearest agent is outside $d_{aggregate}$
    turn toward the local Centroid_{aggregate}, go.
Otherwise, stop.

(Mataric 1995)

Aggregation is the inverse of dispersion. Using the centroid operator with a maximum instead of minimum distance.
BBS Algorithms

• Homing

the ability to find a particular region or location.

Home:
Whenever at home
    stop
otherwise turn toward home, go.

(Mataric 1995)
BBS Algorithms

• Results of Homing BBS

Homing behavior of five robots. Started in an arbitrary initial configuration, four of the robots reached the home region within 100 seconds, and the fifth joined them 30 seconds later. The trails reflect errors in position sensing.
Behavior of Heterogeneous Groups

- In addition to evaluating BBS they compared two distributed algorithms (aggregation & dispersion) based on heterogeneous and hierarchical alternatives.
- Hierarchical - randomly assigned unique ID numbers; higher ID moves while others waited for their turn.
- Homogenous all A moved simultaneously
- Aggregation & dispersion – achieve goals and given sufficient space, can reach a static state.
- The algorithms were evaluated based on the number of steps required to reach that state.
- IM – 20 trails different size 3,5,10,15 and 20.
Behavior of Heterogeneous Groups

• Results of aggregation algorithm

The performance of two different aggregation algorithms based on the number of steps required to reach static aggregated state. Two termination conditions were tested: a single group (data points shown with boxes) and a few stable groups (data points shown with dots). Hierarchical algorithm performance is interpolated with solid lines; homogeneous algorithm performance is interpolated with dots.

(Mataric 1995)
The performance of two different dispersion algorithms based on the number of steps required to reach static dispersed state. Two initial states were tested: a random distribution (data points shown with stars) and a packed distribution (data points shown with crosses). Hierarchical algorithm performance is interpolated with solid lines; homogeneous algorithm performance is interpolated with dots.
Composing Higher-Level Behaviors

- BBS building blocks for more complex interactions. There are two different architecture for combining BBS that allows unbounded number of higher-level behaviors.

- Architecture:
  - COMPLEMENTARY (outputs are executed concurrently)
  - CONTRADICTORY (outputs are mutually exclusive and executed one at a time)

The control architecture for generating group behaviors consists of complementary and contradictory combinations of subsets from a fixed basis behavior set. Complementary combinations are marked with $\oplus$ contradictory combinations with $\otimes$.

(Mataric 1995)
Combining Complementary BBS

• All BBS in the spatial domain are outputs in form of direction and velocity vectors. Sums (Complementary) of this vectors directly produce coherent higher-level behaviors.

• Ex 1. *FLOCKING* behavior
  
  – Combine outputs of *safe-wandering; aggregation; dispersion* and *homing*.

(Mataric 1995)
Combining Complementary BBS

• Example 2 of complementary basis behavior combinations within higher-level task.

\[(\text{Mataric 1995})\]
Combining Contradictory BBS

• Example 3 of contradictory basis behavior combinations for the **FORAGING** behavior.

(Food collection)

*BB are triggered by different sensory conditions, the behaviors collectively result in foraging.*

(Mataric 1995)
Compound Behavior Algorithms

• As described earlier *Flocking* is implemented

Flock:
Sum outputs from Safe--Wander, Disperse, Aggregate, and Home.

*(Mataric 1995)*

*It is a form of structured group movement that minimizes interference, protects individuals, and enables efficient information exchange.*
Results of Compound Behavior

FLOCKING

(Mataric 1995)
Flocking behavior of the same five robots in another trial. The robots maintain a coherent flock, in spite of the often large position errors sensed by individuals. These errors are manifested in the variability in the spacing between the robots as the flock moves.
Results of Compound Behavior

FORAGE

• In foraging, the high-level achievement goal of the group is to collect objects from the environment and deliver them home. (food collection)

```plaintext
Forage:
Whenever crowded? disperse.
Whenever at-home?
  if have-puck? drop-puck
  otherwise disperse
Whenever sense-puck?
  If not have-puck? pickup-puck.
Whenever behind-kin? follow.
```

(Mataric 1995)

Impelented by dispersion; safe-wandering; homing
Results of FORAGE behavior

*Foraging* behavior of six robots. The robots are initiated in the home region. The pucks are initially clustered at the bottom center of the workspace. After *dispersing*, they *safe-wander* and search for pucks, pick them up, and take them home. If they encounter another robot with a puck while they are carrying one, they *follow*, as shown in the third frame of the data. After some time the pucks accumulate in the home region.

*(Mataric 1995)*
Reference
